Caught Between a Rock and a Hard Place?

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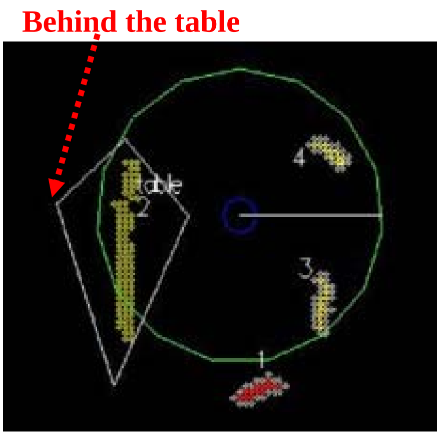
Ever been in a situation where none of the alternatives look promising? In English, the idiom describing that situation is "caught between a rock and a hard place." Now, Guinness, MU's spatially-aware mobile robot, knows that feeling. Well, not exactly, but he knows when he's there. See Figure 1.

Fig. 1. Guinness *between* the "rock" and the "hard place"

"Between" is the latest spatial relationship that has been successfully modeled and embedded into the spatial reasoning framework at the University of Missouri Computational Intelligence Research Laboratory (CIRL). Figure 2 shows a dialog with Guinness with the image being the internal representation of the "world" in grid map format.



(a)

User:	How many objects do you see?
Robot:	I am sensing four objects.
User:	Object 2 is a table.
User:	Describe the scene.
Robot:	There are objects on my front right. The object number 4 is mostly in front of me. The table is behind me.
User:	Go behind the table.

(b)

Fig. 2. (a) The robot situated in an evidence grid map with segmented objects (b) A human-robot dialog from the scene

This ability to reason about the spatial organization of a surrounding environment came about through the conjunction of three research thrusts. Jim Keller has been studying spatial relationships between objects in imagery for almost 15 years. By the mid 1990's several fuzzy set-based definitions had been investigated and a fuzzy logic rule base designed to produce linguistic descriptions of scenes as viewed by an external sensor. Pascal Matsakis (now at the University of Guelph) came to MU after creating the histograms of forces that in our opinion are the most powerful tool to assess relative position information. Figure 3 shows the basic construction of the histogram of forces to encode the relative position of two image objects.

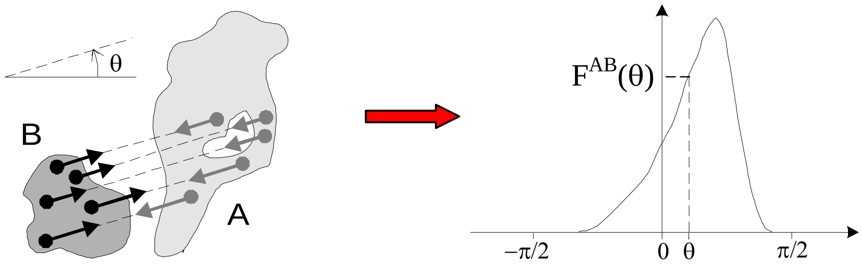


Fig. 3. The histogram of forces, F^{AB}, associated with (A,B) represents the position of object A relative to object B. The value $F^{AB}(\theta)$ is the scalar resultant of forces (black arrows). Each one tends to move B in direction θ.

Matsakis and Keller, with their students, quickly refined and upgraded the linguistic relationship system and discovered how to utilize these histograms to perform scene matching (recovering the pose parameters of the sensors in the process) and most recently, to generate the corresponding object map between the two views, if they are the same. This last capability has the potential to be a robust method to do change detection for surveillance. Figure 4 shows the linguistic description generated by the scene description system.

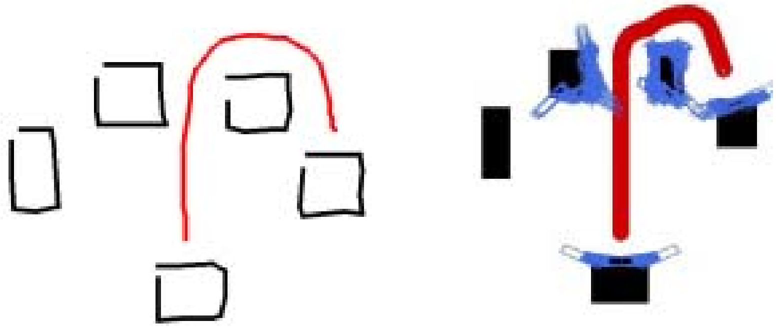
(a) Red objects are **loosely above-left** of the blue buildings

(b) Red objects are **perfectly above** the blue buildings

Fig. 4. Examples of linguistic scene description

Enter Marge Skubic, with expertise in robot intelligence and human-computer interaction. Skubic saw the potential to convert this work into an ego-centered frame with application to mobile robots. Figures 1 and 2 above demonstrate this conversion. Spatial reasoning and spatial language are inherent in how humans communicate. We can tell Guinness to "go behind the box", "move to the right of the nearest object in front of you", or "go between the rock and the hard place."

At MU, we have been pushing this technology to aid in several aspects of robotics and human-robot communication. By using an accurate simulation of how Guinness moves and senses, we have been able to extract spatially triggered route descriptions from a sketched route map (e.g., “go straight until an object is mostly on your left”), building up a qualitative route plan that the real robot can follow. Skubic and her students can now sketch, on a PDA, a route through a rough sketch of the obstacles, download it to Guinness, and have the robot recognize the situation as it moves in the real environment. See Figure 5.



(a) (b)

Fig. 5. (a) The sketched route map (b) The robot traversing the sketched route map

Skubic and Keller are currently working with colleagues at Vanderbilt on an NSF ITR project to study how models of working memory can be used to aid robots in performing complex tasks. The robot spatial reasoning framework is being extended to support this effort.

The ability of a robot to understand and reason about its spatial environment and to communicate effectively with humans is crucial for intelligent behavior. In the CIRL at MU, we are making strides to bridge the gap. Who knows, sometime soon your robot may know that it’s “jumping through hoops” to please you. Figure 6a shows Guinness and the gang, except for Jim Keller. He was on sabbatical in Pensacola (Figure 6b).

(a) (b)

Fig. 6. Guinness and the gang (a) From left to right, George Chronis, Grant Scott, Marge Skubic, Matt Williams, Craig Bailey, Bob Luke, Charlie Huggard, and Sam Blisard (b) Keller and that non-Guiness guy (maybe with one, eh)

Acknowledgments: Much of the research reported here was supported in part by a NATO postdoc fellowship, the Office of Naval Research, the U.S. Naval Research Laboratory and the National Science Foundation. We would also like to acknowledge the contributions of our collaborators at the Naval Research Lab for components on map building, localization and natural language processing: Alan Schultz, Dennis Perzanowski, Bill Adams, Magda Bugajska, and Don Sofge.

For further reading, see:

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